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SPOKANE RIVER WASTELOAD ALLOCATION STUDY -
SUPPLEMENTAL REPORT FOR PHOSPHORUS ALLOCATION

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Summary of Spokane River Wasteload Allocation Issues

The WDOE is in the process of further limiting phosphorus loading into Long Lake, WA to reduce the present rate of eutrophication and enhance Long Lake's water quality. In carrying out this task, the WDOE contracted with the URS Company and Raymond Soltero, Ph.D. (Eastern Washington University) to provide water quality information and analysis of the lake system. Below are listed the major issues and the WDOE decisions regarding those issues.

Issue	URS (1981)	Soltero <i>et al.</i> , (In Press)	WDOE Decision
Methods and data used to establish maximum permissible influent load to Long Lake			
Growing season and data base	June-November 1972-1979	June-November 1972-1980	June-November 1972-1979
Design flow conditions	Chose 1-in-20-year low flow	Used 1-in-15- and 1-in-6-year low flow	Chose 1-in-20-year low flow as design criteria
Acceptable mean seasonal chlorophyll <i>a</i> concentration	presented results for 8, 10, 12, 15 ug/L chl. <i>a</i> . Chose 10 ug/L as design criteria	Presented results for 8, 10, 12 ug/L chl. <i>a</i>	Presented results for 8, 10, 12 ug/L chl. <i>a</i> . Chose 10 ug/L as design criteria
Long Lake Model	Used Dillon (1975) model; presented results for phosphorus retention coefficients of .20, .30, .40. Chose .20 for design criteria.	Used Vollenweider (1976) model; needs no phosphorus retention coefficient	Used Dillon (1975) model; present results for phosphorus retention coefficients .20, .25, .30. Chose .25 for design criteria
Maximum permissible influent load to Long Lake	466 # P/day	609 # P/day	507 # P/day
Methods and data used to establish the existing phosphorus load influent to Long Lake			
Design flow conditions	Chose 1-in-20-year low flow design conditions; however did not consistently use this decision criteria for all inputs	Design flow conditions were not established	Chose the 1-in-20-year low flow event and used it for all inputs
Methods	Total P loads from all sources; underestimated P load from the Little Spokane River	Used mean P load influent to Long Lake during 1978, 1979, and 1980; underestimated P load from Little Spokane River	Used URS (1981) method, incorporated new data, corrected the P load from the Little Spokane River (this correction was responsible for changing the phosphorus retention coefficient in the Dillon (1975) model)
Existing phosphorus load Influent to Long Lake	632 # P/day	452 # P/day	504 # P/day

INTRODUCTION

The Spokane River Wasteload Allocation (SRWA) was initiated as a result of the Spokane Superior Court decision entered on July 24, 1979. The court charged the Washington State Department of Ecology (WDOE) and the Environmental Protection Agency (EPA) with the task of completing a water quality study on the Spokane River system. The stipulation stated:

"...the primary goal of the study shall be to determine the total maximum daily load of phosphorus from all sources which can safely be assimilated into the system. To this end the study objectives will be to: 1) Quantify the levels of phosphorus and related parameters in the river system, 2) Identify the sources of phosphorus contributing to the system, 3) Identify the deleterious effects of the high levels of phosphorus and, 4) to publish conclusions that would recommend a method or methods of slowing the eutrophication process within the said Long Lake impoundment."

A three-year deadline was placed upon completion of the study. As a result, monies were allotted by WDOE and EPA for the project. The WDOE contracted with a consultant, URS Company, to develop the methodology of the SRWA. URS did so in concordance with the court decision and included an example phosphorus allocation. Their findings are reported in a publication entitled *State of Washington, Department of Ecology, Spokane River Wasteload Allocation Study, Phase I* (URS, 1981). The reader is advised to consult the URS (1981) report for background information and the full discussion of the SRWA issues.

Long Lake has been one of the most studied water bodies in the state. The WDOE has contracted with Raymond Soltero, Ph.D. from 1973 to 1980 to conduct limnological studies on Long Lake and the suspected major phosphorus contributor, the City of Spokane sewage treatment plant (STP). This historical work provided much important data for the URS SRWA. Concurrent with the URS study, Soltero and his associates were contracted by WDOE in 1979 to collect additional water quality data for Long Lake during the 1980 growing season. The report of their findings, *The Effect of Continuous Advanced Wastewater Treatment by the City of Spokane on the Trophic Status of Long Lake, WA During 1980* (Soltero, Nichols, and Mires, In Press), also included estimates of the actual and permissible phosphorus loads to Long Lake. The methods by which they arrived at these loads and their conclusions differ somewhat from URS (1981).

The purpose of this Supplemental Spokane River Wasteload Allocation Report is to discuss the minor differences and merits of the URS (1981) and the Soltero *et al.* (In Press) findings. Conclusions will be developed using the analyses of these two investigators plus additional information not previously used by either investigator because of time, budget constraints, or unavailability of data.

LONG LAKE PERMISSIBLE LOAD

The permissible load to Long Lake is the amount of phosphorus which the lake can receive and still maintain a desired water quality. The desired level of water quality is most easily defined in terms of water clarity (URS, 1981). Water clarity during the growing season is primarily affected by the phytoplankton populations present in the lake which, in turn, are responding to the amount of available phosphorus (Soltero *et al.* (1980).

URS, 1981 reported the permissible phosphorus load for Long Lake to be 466 # P/day whereas Soltero *et al.* (In Press) reported 609 # P/day to be the permissible load. The permissible load is established by using an areal phosphorus load versus chlorophyll *a* relationship. The outcome of this relationship is a function of several factors and therefore will change if any one factor is altered. These factors are discussed individually below.

Data Base

One difference between the URS (1981) and Soltero *et al.* (In Press) studies occurred in part because each used different data bases. URS (1981) based their conclusions upon the 1972-1979 data base, whereas Soltero *et al.* (In Press) used 1972-1980 data.

URS did not have the opportunity to review or evaluate the 1980 Long Lake data. It appears that the impact of the May 18, 1980 Mount St. Helens' eruption may have had substantial impact upon the Long Lake system during 1980. Preliminary data from Liberty Lake in Spokane County indicate that the phytoplankton standing crop experienced almost immediate declines following the Mount St. Helens ashfall. The phytoplankton populations also appeared to be much lower throughout the season as a result of this initial shock (Funk, personal communication). It is reasonable to assume that a similar series of events may have occurred in Long Lake. Long Lake would also have received additional ash carried by the river. The Spokane STP also experienced significant ash loading which forced the plant to alter operation for a two-month period. As a result, very high phosphorus loads were discharged to the river during this period.

The phosphorus loadings and mean seasonal chlorophyll *a* concentration for the 1980 growing season (Soltero, unpublished data) do not follow the previously established Dillon loading versus chlorophyll *a* relationship (Soltero, Nichols, and Mires, 1980; URS, 1981). The high 1980 loading with the corresponding low chlorophyll *a* concentration indicates that the growing season was not like any previous years of study. Soltero *et al.* (In Press) used the 1972-1980 data base, but because of the unusually high phosphorus loads and corresponding low chlorophyll *a* response to the high loads which occurred in 1980, they have eliminated the phosphorus loadings and chlorophyll *a* data for June 2 and 16 from the loading versus chlorophyll *a* portion of the report. The loading versus chlorophyll *a* relationship established for Long Lake is based upon the

Long Lake Model

The model establishes the permissible phosphorus load to Long Lake for a given design flow and chlorophyll *a* concentration. Two similar but slightly different models (Dillon 1975; Vollenweider 1976) have been applied to Long Lake by Soltero *et al.* (1980), URS 1981, and Soltero *et al.* (In Press). URS (1981) reported the Dillon (1975) model as the Dillon/Soltero/URS model. For reasons of clarity, this model will be referred to only as the Dillon (1975) model. After inspecting both models, Soltero *et al.* (1980) found the Dillon (1975) relationship to be the model of choice for the Long Lake system. Soltero *et al.* (1980) reported the chlorophyll *a* values predicted by the Dillon model seemed to best follow the actual chlorophyll *a* values observed in the reservoir. URS (1981) also compared both models and concurred with Soltero *et al.* (1980). URS used the Dillon (1975) model to establish their permissible phosphorus load to Long Lake.

Soltero *et al.* (In Press) indicates that the Dillon (1975) relationship as it applies to Long Lake is still an excellent predictor of chlorophyll *a*. However, they further state that the Vollenweider (1976) model is better to use in the SRWA because the Dillon (1975) model is more complicated to use and that its use is not widespread. Their statement concerning the widespread use of the Dillon model is true. The primary reason limnologists do not use the Dillon model as frequently is that it requires more data, hence is more complicated, and is therefore not as easily applied to many systems. Long Lake, unlike the great majority of other lakes, is fortunate to have several years of data to draw upon. The use of these data makes the Dillon (1975) relationship both possible and very reasonable for the Long Lake system. URS 1981, Soltero *et al.* 1980, and Soltero *et al.* (In Press) all agree that the Dillon model is an excellent predictor of chlorophyll *a* in Long Lake. For these reasons, WDOE has used the Dillon (1975) model to establish Long Lake's permissible phosphorus load. ✓ *ibid*

The data and assumptions used with the Dillon (1975) model by Soltero *et al.* (1980); Soltero *et al.* (In Press); and URS (1981) were evaluated by WDOE. It was found that all three documents underestimated the phosphorus load contributed by the Little Spokane River. Correction of this underestimation caused the phosphorus retention coefficients used in the Dillon model to increase.

Little Spokane River Loads

Soltero *et al.* (1980; In Press) and URS (1981) used daily flows recorded at the USGS station 12431000, the Little Spokane River at Dartford, located at river mile 11.4, and total phosphorus concentrations measured near the mouth, river mile 1.1, to calculate the load contributed by the Little Spokane River. Flows recorded at the station near the mouth,

influent phosphorus load during the growing season. The extenuating circumstances present during the 1980 growing season apparently did not allow the algal community to respond typically to high phosphorus loads. Because 1980 was so unusual and atypical, WDOE has evaluated the permissible load to Long Lake based upon the 1972-1979 data base.

Design Flow

The URS (1981) report included a design flow analysis which indicated the 1-in-20-year flow event offered the most protection to the system. The difference in the amount of phosphorus reduction required for the 10- and 20-year recurrence interval was found to be only 7 # P/day. Soltero *et al.* (In Press) used both 6- and 15-year recurrence intervals. The only justification for these choices was that they represented low flow years. The 20-year recurrence interval appears to afford the greatest amount of protection for a small amount of additional treatment cost and therefore has been chosen as the design criteria.

Chlorophyll a

Both Soltero *et al.* (In Press) and URS (1981) presented several chlorophyll a design criteria for Long Lake with the corresponding permissible loads. Each found that the phosphorus reduction required for a chlorophyll a design criterion of 8 ug/L (ug/L = mg/m³) was impossible to achieve. Values of 10 ug/L or greater, however, were found to be possible. Choice of the mean chlorophyll a concentration is dependent upon the desired in-lake water quality and the costs of achieving the needed phosphorus reduction.

URS (1981) found that the water clarity associated with a mean seasonal chlorophyll a concentration of 10 ug/L was both aesthetically pleasing and afforded adequate personal safety for swimmers. They also recognized that the chlorophyll a concentration is a measure of a lake's trophic state. A level of 10 ug/L is regarded by several authors as the demarkation between a eutrophic and mesotrophic water body (URS, 1981). For these reasons 10 ug/L was used as the design criterion.

Soltero *et al.* (In Press) did not state a preference for either 10 or 12 ug/L chlorophyll a design criterion. Their report does, however, establish 10 ug/L as the limit between eutrophic and mesotrophic waters.

For informational purposes, permissible loads required for values of 8, 10, and 12 ug/L chlorophyll a have been included later in the text of this report. For the reasons specified by URS (1981), the mean chlorophyll a concentration selected by WDOE for design purposes is 10 ug/L.

12431900/55B070, are approximately 250 cfs greater than those at Dartford (USGS, 1972b, 1973b, 1977, 1978, 1979, 1980 provisional data). The consistent difference is due to groundwater recharge (Bolke and Vaccaro, 1979). This underestimation of flows also caused the loadings to Long Lake to be underestimated. Corrected flows and loadings are given in Appendix I. Flows near the mouth of the Little Spokane have been determined as a function of flow at the Dartford station. The USGS has used this method at this station since discharge records were begun in 1971 (Nassar, personal communication).

The equation used by USGS for 1979 was available and used for the 1979 loading data; however, equations for previous years were unavailable (Nassar, personal communication). It is common knowledge that flow versus stage in a river is dynamic and may change over time. To minimize this effect, individual equations representing periods of one or two years were generated from published data (USGS 1973b, 1977, 1978, 1979; 1980 provisional data) and applied to the data collected by Soltero *et al.* (1973, 1974, 1975, 1976, 1978, 1979, 1980). The flows from Dartford and the equations used to determine the flows near the mouth are also given in Appendix I. One other minor error in the URS (1981) work was the omission of all September 17 data from the 1979 data base. The results of the corrected analysis are enclosed (Table 1).

Retention Coefficient

As stated previously, the loading correction caused the phosphorus retention coefficient to increase because the influent load changed while the effluent load remained the same. The URS (1981) report suggested and used a retention coefficient of .20 as a constant to establish the permissible load for Long Lake. The corrected data now indicate that the coefficient should be greater than .20. The observed coefficients range from .24 to .46 with a mean of .34. A coefficient of .25 being at the low end of the range maintains the maximum amount of safety for the system. A retention coefficient of .30 also could be used as a reasonable choice as it falls well below the mean and has occurred in both 1972 and 1978 (low flow years which approach design conditions). It however does not offer as much of a safety margin as does the .25 value. For comparative purposes, permissible phosphorus loads have been calculated for $R = .20, .25, \text{ and } .30$ and chlorophyll *a* concentrations of 8, 10, and 12 ug/L (Table 2). The permissible load to Long Lake assuming the 1-in-20-year flow event, a phosphorus retention coefficient of 0.25, and a mean seasonal chlorophyll *a* concentration of 10 ug/L is 507 # P/day.

The relationship of areal phosphorus loading $L(1-R)/P$ versus mean seasonal chlorophyll *a* has changed; however, regression analysis indicates it still remains very good (the correlation coefficient, $r^2 = .939$). The line is best represented by the equation $y = 9.86 (x) + 5.95$ (Figure 1).

Table 1. Mean daily influent and effluent loads, seasonal areal phosphorus load (L), phosphorus retention coefficient (R), flushing rate (P), the Dillon (1975) loading relationship $L(1-R)/P$, and the mean seasonal chlorophyll *a* observed over the 183-day growing season in Long Lake from June to November for all study years.

Year	Load in NM + LSR # P/day	Load out Dam # P/day	$\frac{L}{gP/m^2/season}$	R	P	$\frac{L(1-R)}{P}$	Chl <i>a</i>
1972	2268	1584	9.04	.30	8.77	0.72	12.34
1973	2044	1258	8.15	.38	3.93	1.29	19.86 ¹
1974	1981	1503	7.90	.24	10.13	0.59	10.90
1975	2290	1239	9.13	.46	9.46	0.52	11.87
1977	1531	894	6.10	.42	3.72	0.95	14.12
\bar{X} =	2023	1296	8.07				13.82
1978	480	334	1.91	.30	5.59	0.24	8.79
1979	520	380	2.07	.28	4.68	0.32	9.44
\bar{X} =	500	357	1.99	.34 ²			9.12

¹ June-October.

² Mean of all study years.

Table 2. Permissible loading to Long Lake assuming chlorophyll *a* concentrations of 8, 10, and 12 ug/L; design flow = 2535 cfs; and phosphorus retention coefficients of .20, .25, and .30.

Chl <i>a</i> (ug/L)	R = .20		R = .25		R = .30	
	gP/m ²	# P/day	gP/m ²	# P/day	gP/m ²	# P/day
8	0.97	243	1.04	261	1.11	278
10	1.90	477	2.02	507	2.17	544
12	2.82	707	3.01	755	3.22	808

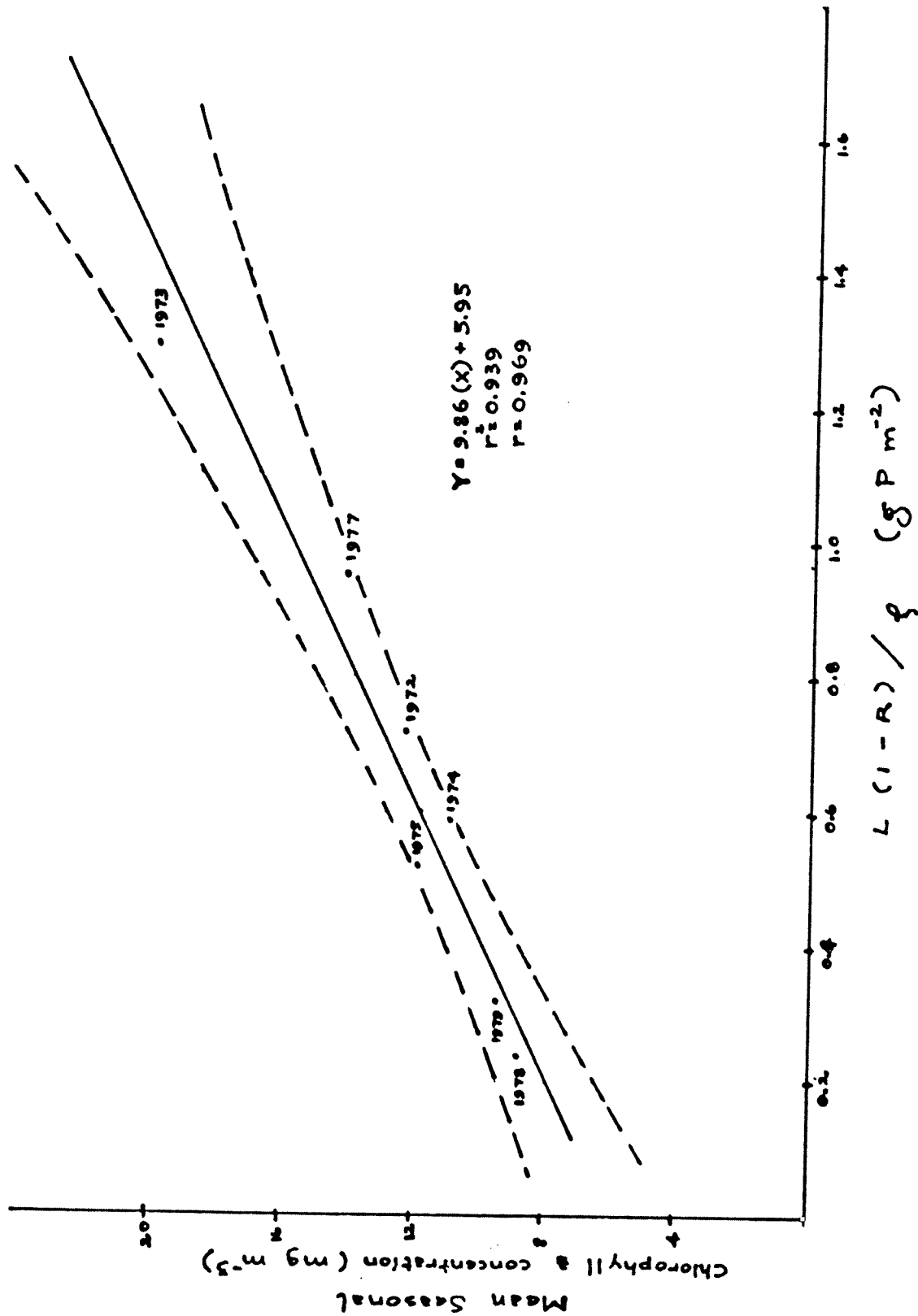


Figure 1. Total areal phosphorus load $L(1-R)/P$ (g P m^{-2}) and mean chlorophyll a concentrations (mg m^{-3}) for Long Lake, WA for 1972-1975 and 1977-1979 during the growing season (June-November). The dashed lines represent the 95% confidence interval.

EXISTING LONG LAKE INFLUENT LOAD

The next step in the allocation process is to estimate the amount of phosphorus entering Long Lake. Comparisons are then made between the permissible and the existing load to determine if the system is over-, completely-, or under-allocated. Each of the two investigators used a different method to determine the phosphorus load entering Long Lake.

Soltero *et al.* (In Press) estimated the current Long Lake load to be 452 # P/day. This value was obtained by taking an average of the three years the City of Spokane's STP has been removing phosphorus (1978, 1979, 1980). It includes the underestimated Little Spokane River loads discussed earlier. This method was not considered a viable alternative to the URS (1981) method because neither of the flows in 1978 or 1979 matched design flow conditions. The 1980 growing season data also were not appropriate for reasons stated previously. The method used by Soltero *et al.* (In Press) also does not address phosphorus loading from specific point sources, a need which must be met if limitation of individual dischargers becomes necessary.

URS (1981) estimated the phosphorus load coming into Long Lake from all dischargers, nonpoint sources, tributaries, and groundwater during the 1-in-20-year flow event to be 632 # P/day. This value does not include phosphorus lost to the aquifer and it treats phosphorus as a conservative parameter. These provisions overestimate the phosphorus load to the lake and in effect offer significant amounts of protection to the system. Since a margin of safety is desired, it is appropriate to use these assumptions.

As with the Long Lake model, determination of the existing load to Long Lake may be affected by several factors. In order to evaluate the loads reported by URS (1981), WDOE inspected the data and assumptions used for the point source loadings; design flow conditions; and tributary phosphorus concentrations, and made adjustments where needed.

Point Source Loading

The point source input data were altered to reflect changes caused by additional data. This was true for the Spokane Industrial Park load which decreased from 17 to 15 # P/day; Kaiser Aluminum increased from 0 to 3 # P/day; Inland Empire Paper decreased from 14 to 12 # P/day; and Millwood STP decreased from 9 to 2 # P/day. Millwood's load also declined because an error was found in the flow transmitted from WDOE to URS. The Spokane STP load was determined from monthly loads during the times when advanced wastewater treatment was functioning routinely. This value changed very slightly from 182 to 184 # P/day. All of the data used for this analysis are presented in Appendix II.

Design Flow Conditions

Discharges URS (1981) used for Post Falls, Hangman Creek, and Little Spokane River also were evaluated. It was found that the

example allocation used flows which did not consistently represent the 1-in-20-year flow event. Flows at Long Lake Dam and Hangman Creek represented design conditions, whereas the Post Falls and Little Spokane River flows did not. We believe it is appropriate to use the design flow for all river or stream inputs so that consistency is maintained and so other design flows may be evaluated under like conditions if this ever becomes necessary. We realize that the magnitude of the flow event chosen by this method also is a function of the period of record at each individual site. Because of this, the actual year in which the low flow event occurred may not be the same for all stations. It would be best if a similar data base existed for all stations so flows could be used from all tributaries for that given year. The 1-in-20-year design flow for Post Falls changes from 1600 cfs to 1352 cfs. Coincidentally, the flow of 1352 cfs used for Post Falls occurred in the same year the 2535 cfs design flow occurred at Long Lake. The Little Spokane River flow changed from 380 cfs to 352 cfs.

Phosphorus Concentrations

WDOE evaluated the phosphorus concentrations used in the URS (1981) example. To accomplish this, a phosphorus loading versus flow relationship was plotted and regressed to determine how loads varied with flow. Loads at Stateline were generated from USGS data (1972a and b, 1973a and b, 1974a, 1975, 1976, 1977, 1978, 1979; 1980 provisional data), Funk *et al.* (1973 and 1975), and EPA unpublished data. The relationship indicated an Idaho inflow concentration of .006 mg/L-P is appropriate for design flow conditions. URS (1981) had used a concentration of .014 mg/L-P. Hangman Creek and the Little Spokane River also were analyzed in the same way. Phosphorus concentrations declined from .44 to .08 mg/L-P for Hangman Creek and declined from .024 to .015 mg/L-P for the Little Spokane River. The Little Spokane River analysis nicely shows the effect of the groundwater input on the load. The load in Hangman Creek declines to very low levels during low flows. All relationships, equations, and graphs used in the evaluation of loading versus flow may be found in Appendix III.

Current Existing Load

The final outcome of the river loading analyses may be found in Table 3. The estimated load to Long Lake under design conditions changed from 632 (URS, 1981) to 504 # P/day.

PHOSPHORUS ALLOCATION

The above analysis indicates that the Spokane River is currently at complete allocation. Any increase in the current phosphorus loads must be offset by a decrease somewhere else. Phosphorus input from nonpoint sources, tributaries, and dischargers having less than 1 mgd flow can be altered very little; therefore, phosphorus loading can only be managed

Table 3. Present loading to Long Lake assuming the 1-in-20-year flow event for the period June-November. All dischargers at secondary treatment.

	<u># P/day</u>
Idaho Inflow	47
Idaho STPs	126
Liberty Lake STP	0
Spokane Industrial Park	15
Kaiser (net)	3
Spokane Valley Runoff	13
Inland Empire Paper	12
Millwood STP	2
City CSO	26
Hangman Creek	6
Spokane STP	1440 (184)*
Spokane Urban Runoff	24
N.W. Terrace STP	8
North Spokane Runoff	4
Little Spokane River	28
Groundwater Inflow	<u>6</u>
 Total System Load	 1760
 Net =	 504

*Represents current plant loading with current 89.8 percent removal efficiency.

by control of the major point discharges. Nonpoint sources comprise 30.4 percent (154 # P/day) of the total load. This leaves all dischargers with the combined total of 353 # P/day.

Table 4 presents several different alternatives which may be possible options for the Spokane River system. The following assumptions were used to generate Table 4.

1. Both the Coeur d'Alene and Post Falls secondary STPs were assumed to remove 20 percent of the influent phosphorus. The influent phosphorus concentration of 9.4 mg/L as P was determined by dividing the secondary effluent concentration (URS, 1981) by .80.
2. The Liberty Lake STP average influent phosphorus concentration was assumed to be 7.9 mg/L as P which was determined by dividing the secondary effluent concentration given in Kennedy (1978) by .80.
3. The Spokane STP was assumed to have an influent phosphorus concentration of 6.29 mg/L as P. The plant has maintained a phosphorus removal rate of 89.8 percent. This is higher than their NPDES permittled level of 85 percent removal. The average effluent phosphorus concentration with the 89.8 percent efficiency is 0.64 mg/L as P (Appendix II).
4. Secondary treatment was assumed to remove 20 percent of the influent phosphorus load.
5. The minor dischargers' contribution remained at 40 # P/day in the 1990 condition. This may not be accurate; however, projections were unavailable.
6. The nonpoint sources were increased to the same levels reported by URS (1981) for the 1990 condition.

Case 1 in Table 4 is the current situation for the river which shows it fully allocated. Almost all of the near future and future cases indicate that other measures must be employed if the permissible load is to be met. The presentation of these options is not to infer that these are the only or the preferred options available.

FUTURE WORK

At present, contracts have been let to collect additional water quality data on the Long Lake system. Future refinements of the Spokane River Wasteload Allocation will be made when the finalized data become available, if new conditions or methodologies merit such a change.

Table 4. Summary of possible options for allocating phosphorus among municipal wastewater treatment plants in the Spokane River system.

	Flow (mgd)	% P Removal	Phosphorus Load (# P/day)						Total Load	Permissible Load	Net #/day	Balance* (mgd)
			Post Falls STP	Coeur d'Alene STP	Liberty Lake STP	Spokane STP	All Other Dischargers	Nonpoint				
<u>Present Conditions</u>												
Case 1												
Post Falls	0	--	0	126	0	184	40	154	504	507	+3	+0.4
Coeur d'Alene	2.0	20										
Liberty Lake	0	--										
Spokane**	34.3	89.8										
Case 2												
Post Falls	0	--	0	126	0	270	40	154	590	507	-83	-10.5
Coeur d'Alene	2.0	20										
Liberty Lake	0	--										
Spokane	34.3	85										
<u>Near Future</u>												
Case 1												
Post Falls	1.0	20	63	126	53	184	40	154	620	507	-113	-14.3
Coeur d'Alene	2.0	20										
Liberty Lake	1.0	20										
Spokane	34.3	89.8										
Case 2												
Post Falls	1.0	20	63	23	20	184	40	154	484	507	+23	+2.9
Coeur d'Alene	2.0	85										
Liberty Lake	2.0	85										
Spokane	34.3	89.8										
Case 3												
Post Falls	1.0	85	12	23	10	270	40	154	509	507	-2	-0.3
Coeur d'Alene	2.0	85										
Liberty Lake	1.0	85										
Spokane	34.3	85										
Case 4												
Post Falls	1.0	85	12	23	10	184	40	154	423	507	+84	+10.7
Coeur d'Alene	2.0	85										
Liberty Lake	1.0	85										
Spokane	34.3	89.8										
Case 5												
Post Falls	1.0	20	63	23	10	270	40	154	570	507	-63	-8.0
Coeur d'Alene	2.0	85										
Liberty Lake	1.0	85										
Spokane	34.3	85										
<u>Future (1990)</u>												
Case 1												
Post Falls	1.0	20	63	41	53	347	40	154	698	507	-191	-24.2
Coeur d'Alene	3.5	85										
Liberty Lake	1.0	20										
Spokane	44.0	85										
Case 2												
Post Falls	1.0	20	63	41	53	236	40	154	587	507	-80	-10.2
Coeur d'Alene	3.5	85										
Liberty Lake	1.0	20										
Spokane	44.0	89.8										
Case 3												
Post Falls	1.0	20	63	41	30	347	40	186	707	507	-200	-25.4
Coeur d'Alene	3.5	85										
Liberty Lake	3.0	85										
Spokane	44.0	85										
Case 4												
Post Falls	1.0	20	63	41	30	236	40	186	596	507	-89	-11.3
Coeur d'Alene	3.5	85										
Liberty Lake	3.0	85										
Spokane	44.0	89.8										

*Assumes influent phosphorus concentration of 6.29 mg/L and 85% removal.

**Assumes Spokane STP is currently achieving 89.8% removal which is greater than 85% NPDES requirement.

CONCLUSIONS

1. The data base used for setting the permissible load to Long Lake is the growing season, June-November, from 1972-1979. The year 1980 is not included because of the higher phosphorus loading and atypical low chlorophyll a response apparently caused by the Mount St. Helens eruption. Additional data will indicate if 1980 was an unusual year.
2. The design flow condition is the 1-in-20-year flow event for all parts of the system.
3. The acceptable mean seasonal chlorophyll a concentration in Long Lake is 10 ug/L.
4. The Dillon (1975) model is used with a phosphorus retention coefficient of .25 to set the permissible load.
5. The maximum permissible load to Long Lake is 507 # P/day.
6. The existing load to Long Lake is established by estimation of the input from all sources under design conditions. Loads contributed by the Little Spokane River are calculated with flows taken at the station near the mouth.
7. Existing phosphorus load influent to Long Lake under design conditions is 504 # P/day.
8. The Spokane River is at complete allocation presently; however, several management options are available.
9. This work will be evaluated as new data or conditions merit.

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APPENDIX I

Phosphorus loading data, 1972.

Date	Nine Mile			Little Spokane River				Dam		
	Q (cfs)	T-P04 (mg/L)	Load (# P/day)	Q _D (cfs)	Q _m ² (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cfs)	T-P04 (mg/L)	Load (# P/day)
6/07	28,113	.12	5,928	244	448	.05	39	27,540	.12	5,807
6/24	14,475	.12	3,052	214	439	.15	116	15,620	.14	3,843
7/01	3,828	.23	1,547	179	409	.19	137	3,760	.17	1,123
7/08	4,688	.12	988	159	391	.20	137	5,360	.13	1,224
7/15	4,526	.17	1,352	155	387	.10	68	5,510	.13	1,259
7/22	4,035	.27	1,914	153	386	.14	95	4,730	.18	1,496
7/29	2,725	.44	2,107	143	377	.14	93	1,920	.15	506
8/05	2,158	.54	2,048	138	372	.14	92	1,360	.17	406
8/14	1,592	.53	1,482	132	367	.11	71	2,150	.16	604
8/21	2,068	.58	2,108	141	375	.11	72	3,080	.24	1,299
8/28	2,604	.41	1,876	143	377	.15	99	3,530	.25	1,551
9/05	2,096	.46	1,694	135	370	.13	85	3,130	.19	1,045
9/11	1,314	.73	1,685	136	371	.12	78	2,980	.29	1,519
9/18	1,604	.82	2,311	135	370	.11	72	1,910	.35	1,175
9/25	1,996	.52	1,824	155	387	.11	75	2,830	.28	1,392
10/21	2,103	.73	2,698	143	377	.12	79	2,280	.18	721
11/24	1,891	.73	2,426	170	401	.16	113	2,850	.39	1,953
				$Q_m = .88 (Q_D) + 251$						
				$r = 0.968$						
mean daily load = 2,179 #P				mean daily load = 89 # P						
				mean daily load = 1,584 # P						

¹Q_D = Flow at Dartford.

²Q_m = Flow near mouth.

Mean daily influent load = 2,268 # P
Mean daily effluent load = 1,584 # P
Total seasonal load = 9.04 gP/m²
Total seasonal effluent load = 6.31 gP/m²

Phosphorus loading data, 1973.

Date	Nine Mile			Little Spokane River				Dam		
	Q (cms)	T-PO ₄ (mg/L)	Load (# P/day)	Q _D ¹ (cfs)	Q _m ² (cfs)	T-PO ₄ (mg/L)	Load (# P/day)	Q (cms)	T-PO ₄ (mg/L)	Load (# P/day)
6/19	119.40	.41	3,037	132	367	.14	90	139.24	.20	1,728
6/26	80.74	.42	2,104	126	362	.09	57	79.81	.16	792
7/02	81.02	.33	1,659	111	349	.09	55	85.47	.18	955
7/10	57.05	.47	1,664	101	340	.08	48	92.26	.24	1,374
7/16	40.55	.78	1,962	97	336	.07	41	71.32	.16	708
7/24	30.22	.70	1,313	85	326	.08	46	35.66	.32	708
7/31	25.98	.92	1,483	84	325	.10	57	39.90	.39	965
8/06	27.62	1.13	1,936	82	323	.15	85	44.71	.36	999
8/21	36.51	.74	1,676	92	332	.08	47	51.51	.44	1,406
8/28	35.57	.68	1,501	103	342	.08	48	42.45	.46	1,212
9/04	42.39	.75	1,973	111	349	.06	37	58.02	.42	1,512
9/12	70.52	.53	2,319	106	344	.08	48	76.98	.53	2,531
9/29	66.19	.45	1,848	131	366	.10	64	51.22	.38	1,208
10/20	62.94	.40	1,562	132	367	.09	58	52.36	.30	975
11/20	122.68	.49	3,730	271	489	.14	120	144.90	.20	1,798

$$Q_m = .88 (Q_D) + 251$$

$$r = 0.968$$

mean daily load = 1,984 # P

mean daily load = 1,258 # P

¹Q_D = Flow at Dartford.

²Q_m = Flow near mouth.

Mean daily influent load = 2,044 # P
 Mean daily effluent load = 1,258 # P
 Total seasonal load = 8.15 gp/m²
 Total seasonal effluent load = 5.02 gp/m²

Phosphorus loading data, 1974.

Date	Nine Mile			Little Spokane River				Dam		
	Q (cms)	T-P04 (mg/L)	Load (# P/day)	Q _D (cfs)	Q _m ² (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cms)	T-P04 (mg/L)	Load (# P/day)
6/08	796.71	.13	6,426	438	636	.16	179	812.78	.13	6,556
6/25	744.71	.10	4,621	271	489	.10	86	713.16	.07	3,097
7/01	547.38	.10	3,396	238	460	.10	81	557.79	.10	3,461
7/09	133.77	.18	1,494	253	474	.06	50	163.86	.05	508
7/15	128.09	.13	1,033	234	457	.06	48	146.03	.06	544
7/22	114.36	.24	1,703	229	452	.08	64	129.05	.09	721
7/29	90.73	.22	1,238	194	422	.08	59	105.28	.09	588
8/05	92.26	.27	1,546	184	413	.08	58	103.58	.13	835
8/12	76.13	.26	1,228	176	406	.06	43	63.96	.16	635
8/19	65.09	.43	1,737	174	404	.06	43	56.88	.17	600
8/26	44.43	.37	1,020	169	400	.07	49	93.11	.20	1,155
9/03	53.77	.47	1,568	163	394	.09	62	84.33	.19	994
9/09	53.49	.55	1,825	169	400	.07	49	94.52	.17	997
9/13	39.34	.32	781	173	403	.07	50	97.63	.21	1,272
9/23	47.26	.35	1,026	170	401	.07	49	90.28	.28	1,568
9/30	48.39	.30	901	170	401	.06	42	82.92	.20	1,029
10/21	61.19	.32	1,215	181	410	.08	58	103.58	.18	1,157
11/25	89.43	.31	1,720	330	541	.12	114	119.14	.18	1,331
$Q_m = .88 (Q_D) + 251$										
$r = 0.968$										
mean daily load = 1,915 # P			mean daily load = 66 # P			mean daily load = 1,503 # P				

¹Q_D = Flow at Dartford.

²Q_m = Flow near mouth.

Mean daily influent load = 1,981 # P
Mean daily effluent load = 1,503 # P
Total seasonal load = 7.90 gP/m²
Total seasonal effluent load = 5.99 gP/m²

Phosphorus loading data, 1975.

Date	Nine Mile				Little Spokane River				Dam	
	Q (cms)	T-P04 (mg/L)	Load (# P/day)		Q _D (cfs)	Q _m ² (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cms)	T-P04 (mg/L)
6/18	556.60	.08	2,763		325	537	.12	113	565.77	.11
7/01	138.92	.22	1,896		273	491	.14	121	146.68	.14
7/15	179.05	.21	2,333		278	496	.51	444	186.89	.08
7/29	98.62	.41	2,509		185	414	.12	87	103.92	.11
8/12	43.05	.46	1,229		170	401	.14	99	47.86	.11
8/25	99.82	.36	2,230		195	423	.13	97	105.34	.14
9/10	74.87	.30	1,394		176	406	.11	78	79.85	.18
9/23	92.40	.34	1,949		167	398	.05	35	97.13	.15
10/21	99.17	.39	2,400		188	416	.14	102	104.49	.17
11/18	126.60	.37	2,906		209	435	.15	115	132.52	.18

$$Q_m = .88 (Q_D) + 251$$

$$r = 0.968$$

$$\text{mean daily load} = 2,161 \text{ \# P}$$

$$\text{mean daily load} = 129 \text{ \# P}$$

$$\text{mean daily load} = 1,239 \text{ \# P}$$

$$^1 Q_D = \text{Flow at Dartford.}$$

$$^2 Q_m = \text{Flow near mouth.}$$

$$\begin{aligned} \text{Mean daily influent load} &= 2,290 \text{ \# P} \\ \text{Mean daily effluent load} &= 1,239 \text{ \# P} \\ \text{Total seasonal load} &= 9.13 \text{ gP/m}^2 \\ \text{Total seasonal effluent load} &= 4.94 \text{ gP/m}^2 \end{aligned}$$

Phosphorus loading data, 1977.

Date	Nine Mile			Little Spokane River				Dam	
	Q (cms)	T-P04 (mg/L)	Load (# P/day)	Q _D (cfs)	Q _m ² (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cms)	T-P04 (mg/L)
6/14	125.06	.28	2,173	141	428	.08	60	128.86	.09
6/28	63.05	.41	1,604	112	397	.20	140	76.41	.14
7/12	55.95	.40	1,389	103	388	.06	41	63.39	.11
7/26	48.31	.54	1,619	103	388	.06	41	59.15	.13
8/09	43.64	.55	1,489	98	382	.11	74	45.56	.24
8/23	38.88	.49	1,182	96	380	.09	60	45.00	.27
9/06	61.81	.33	1,266	116	401	.06	42	63.39	.44
9/20	60.28	.30	1,122	120	406	.08	57	63.11	.25
10/14	68.29	.28	1,186	124	410	.08	58	78.39	.31
11/16	80.57	.33	1,650	161	449	.07	55	100.47	.16

$$Q_m = 1.06 (Q_D) + 278$$

$$r = 0.97$$

$$\text{mean daily load} = 1,468 \text{ \# P}$$

$$\text{mean daily load} = 894 \text{ \# P}$$

¹Q_D = Flow at Dartford.

²Q_m = Flow near mouth.

$$\begin{aligned} \text{Mean daily influent load} &= 1,531 \text{ \# P} \\ \text{Mean daily effluent load} &= 894 \text{ \# P} \\ \text{Total seasonal load} &= 6.10 \text{ gP/m}^2 \\ \text{Total seasonal effluent load} &= 3.56 \text{ gP/m}^2 \end{aligned}$$

Phosphorus loading data, 1978.

Date	Nine Mile			Little Spokane River				Dam	
	Q (cms)	T-P04 (mg/L)	Load (# P/day)	Q_D^1 (cfs)	Q_m^2 (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cms)	T-P04 (mg/L)
6/20	174.7	.05	542	195	485	.10	85	180.8	.06
7/05	151.8	.12	1,130	180	469	.14	115	144.1	.05
7/18	82.7	.06	308	159	447	.10	79	79.2	.07
8/01	54.7	.07	238	127	413	.09	65	53.2	.06
8/14	47.8	.07	208	122	408	.08	57	54.1	.03
8/29	78.2	.06	291	136	423	.10	74	83.2	.08
9/12	76.5	.08	380	157	445	.10	78	86.3	.04
10/06	74.1	.08	368	143	430	.06	45	98.5	.06
11/03	79.3	.05	246	148	435	.02	15	81.5	.05
$Q_m = 1.06 (Q_D) + 278$ $r = 0.97$									mean daily load = 334 # P
Q_D^1 = Flow at Dartford. Q_m^2 = Flow near mouth.									mean daily influent load = 480 # P mean daily effluent load = 334 # P Total seasonal load = 1.91 gp/m ² Total seasonal effluent load = 1.33 gp/m ²

Phosphorus loading data, 1979.

Date	Nine Mile			Little Spokane River				Dam		
	Q (cms)	T-P04 (mg/L)	Load (# P/day)	Q_D^1 (cfs)	Q_m^2 (cfs)	T-P04 (mg/L)	Load (# P/day)	Q (cms)	T-P04 (mg/L)	Load (# P/day)
6/08	341.4	.06	1,271	157	423	.07	52	353.5	.07	1,535
6/25	129.2	.07	561	124	384	.11	74	136.7	.06	509
7/09	81.3	.09	454	116	375	.10	66	89.1	.05	276
7/23	58.5	.06	218	102	358	.10	63	64.8	.06	241
8/06	44.0	.12	328	95	350	.10	61	65.9	.05	204
8/20	36.9	.08	183	105	362	.04	25	30.8	.01	19
9/04	63.4	.11	433	130	391	.08	55	70.5	.04	175
9/17	71.7	.09	400	116	375	.04	26	82.1	.04	204
10/01	69.5	.10	431	120	380	.05	33	71.3	.05	221
11/05	76.2	.09	426	146	410	.06	43	77.0	.07	334

$$Q_m = 1.18 (Q_D) + 238$$

mean daily load = 470 # P

mean daily load = 372 # P

¹ Q_D = Flow at Dartford.

² Q_m = Flow near mouth.

Mean daily influent load = 520 # P
 Mean daily effluent load = 372 # P
 Total seasonal load = 2.07 gP/m²
 Total seasonal effluent load = 1.48 gP/m²

APPENDIX II

Phosphorus loads of Spokane River point sources monitored during three surveys -- 3/80 to 2/81.

Date	Total P (mg/l)	Discharge MGD	Phosphorus Load lbs/day	Mean Phosphorus Load (lbs/day)
<u>SPOKANE INDUSTRIAL PARK</u>				
3/31 - 4/01/80	1.6	0.61	8.2	$\bar{X} = 15 \pm 7$
6/10 - 6/11/80	2.9	0.69	16.7	
2/10 - 2/11/81	3.7	0.78	24.1	
<u>KAISER TRENTWOOD PLANT</u>				
<u>Sanitary</u>				
3/31 - 4/01/80	0.9	--	--	$\bar{X} = 3 \pm 1$
6/10 - 6/11/80	3.1	0.165	4.3	
2/10 - 2/11/81	1.6	0.19	2.5	
<u>Industrial</u>				
3/31 - 4/01/80	<0.1	0.070	<0.06	$\bar{X} = 0.6 \pm 0.5$
6/10 - 6/11/80	1.3	0.070	0.76	
2/10 - 2/11/81	2.3	0.054	1.04	
<u>Combined Effluent (sanitary, industrial, and cooling water)^{1/}</u>				
3/31 - 4/01/80	0.08	26.6	17.8	$\bar{X} = 17 \pm 3$
6/10 - 6/11/80	0.06	27.3	13.7	
2/10 - 2/11/81	0.09	26.3	19.8	
<u>INLAND EMPIRE PAPER CO.</u>				
3/31 - 4/01/80	0.43	2.15	7.7	$\bar{X} = 12 \pm 4$
6/10 - 6/11/80	0.8	2.19	14.6	
2/10 - 2/11/81	0.75	2.4	15.0	
<u>MILLWOOD STP</u>				
6/10 - 6/11/80	16	0.015	2.00	$\bar{X} = 1.5 \pm 0.7$
2/10 - 2/11/81	2.8	0.04	0.94	
<u>SPOKANE STP</u>				
3/31 - 4/01/80	0.80	36.	240	$\bar{X} = 200 \pm 50$ ^{2/}
6/10 - 6/11/80	3.4	36	1022 ^{2/}	
2/10 - 2/11/81	0.70	28.4	165	
<u>N.W. TERRACE</u>				
3/31 - 4/01/80	8.5	0.12	8.5	$\bar{X} = 8.3 \pm 0.6$
6/10 - 6/11/80	8.4	0.11	7.7	
2/10 - 2/11/81	7.0	0.15	8.8	

^{1/} Total phosphorus load from Kaiser at Trentwood considered to be near 0; largest volume of water taken from the river for cooling, then returned as combined effluent.

^{2/} Spokane STP was bypassing AWT due to Mt. St. Helens ash problems. Mean value does not contain 6/10/80 value.

Monthly mean phosphorus influent concentration, load, and discharge from Spokane STP for the period January 1978 to April 1981 obtained from STP Daily Monitoring Records (DMRs).

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Month
Year	31	28 ^{1/}	31	30	31	30	31	31	30	31	30	31	Number of days
1978	5.71*	6.18*	5.72*	5.06*	6.74	5.74	5.17	5.85	6.67	6.66	6.93	7.29	Monthly inf. P conc.
	1010*	504*	369*	291*	199	98.5	231	115	154	198	214	194	Monthly mean loads
	44.5*	40.0*	34.6*	37.9*	40.9	35.3	38.0	37.1	34.1	30.4	30.5	31.05	Monthly mean MGD
1979	6.59	5.02	5.67	6.73	5.31	6.27	5.68	5.64	7.40	8.30	6.32	5.99	Monthly inf. P conc.
	206	201	164	172	130	163	129	197	237	233	164	182	Monthly mean loads
	31.6	46.0	34.3	29.5	36.6	31.6	32.4	33.5	32.7	31.0	26.6	29.9	Monthly mean MGD
1980	6.05	6.56	6.78	7.10	6.05 ^{2/}	5.79 ^{2/}	5.42	5.94	6.47	7.04	6.58	5.14	Monthly inf. P conc.
	207	196	192	188	575 ^{2/}	827 ^{2/}	226	181	182	174	191	171	Monthly mean loads
	35.0	36.8	30.4	29.2	35.4 ^{2/}	35.3 ^{2/}	34.3	33.2	29.9	28.9	33.8	36.5	Monthly mean MGD
1981	6.41	5.79	6.43	5.86									Monthly inf. P conc.
	233	189	150	202									Monthly mean loads
	32.4	33.4	31.6	31.0									Monthly mean MGD

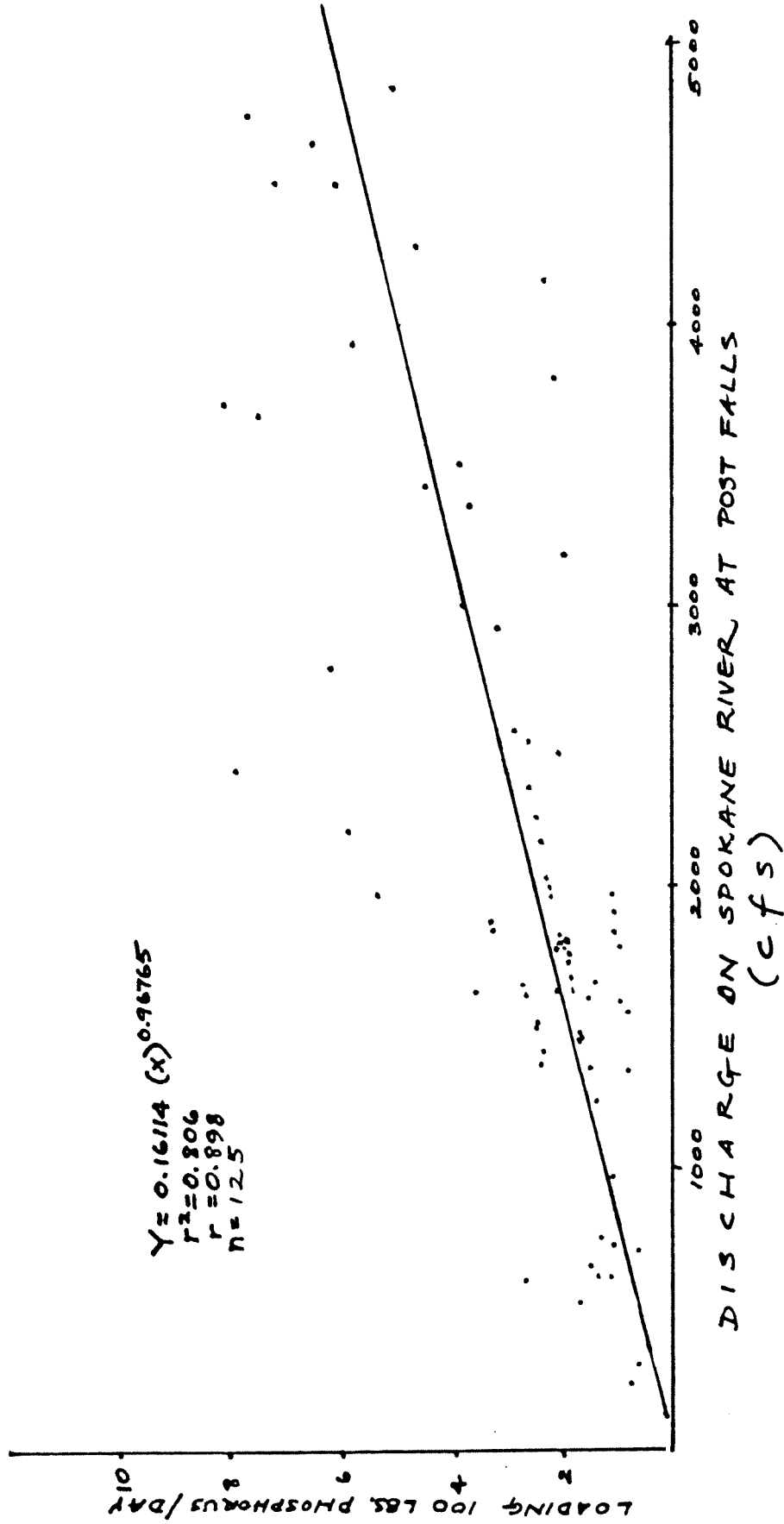
Mean influent phosphorus concentration of all days except as noted: 6.29 mg/L P
Mean effluent phosphorus concentration of all days except as noted: 0.64 mg/L
Mean phosphorus load of all days except as noted: 184 # P/day
Mean discharge of all days except as noted: 34.3 MGD
Removal efficiency: 89.8 percent

^{1/} February 1980 had 29 days.

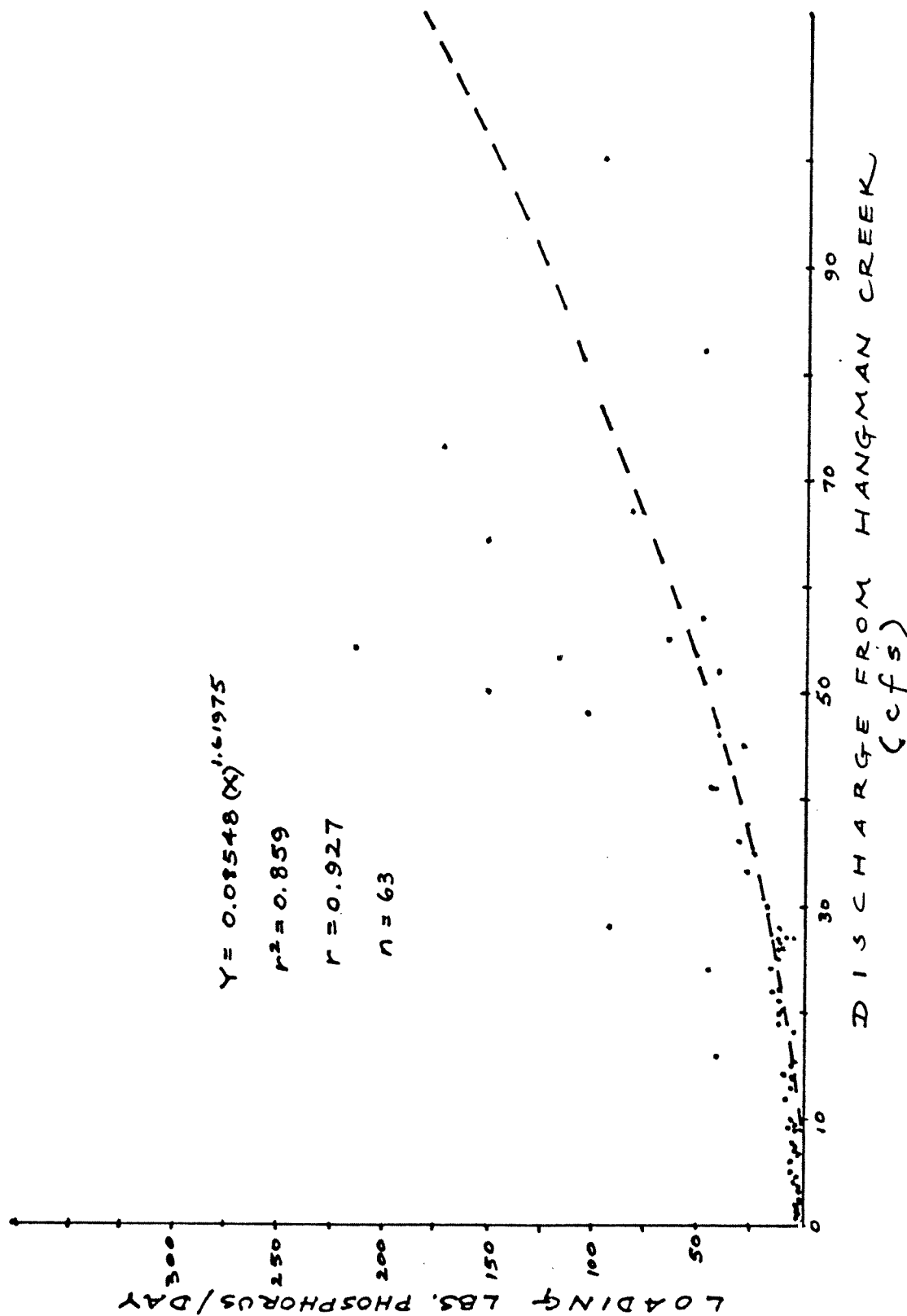
^{2/} Data not used, Mt. St. Helens ash prevented AWT.

* Data not used, AWT not under normal operation.

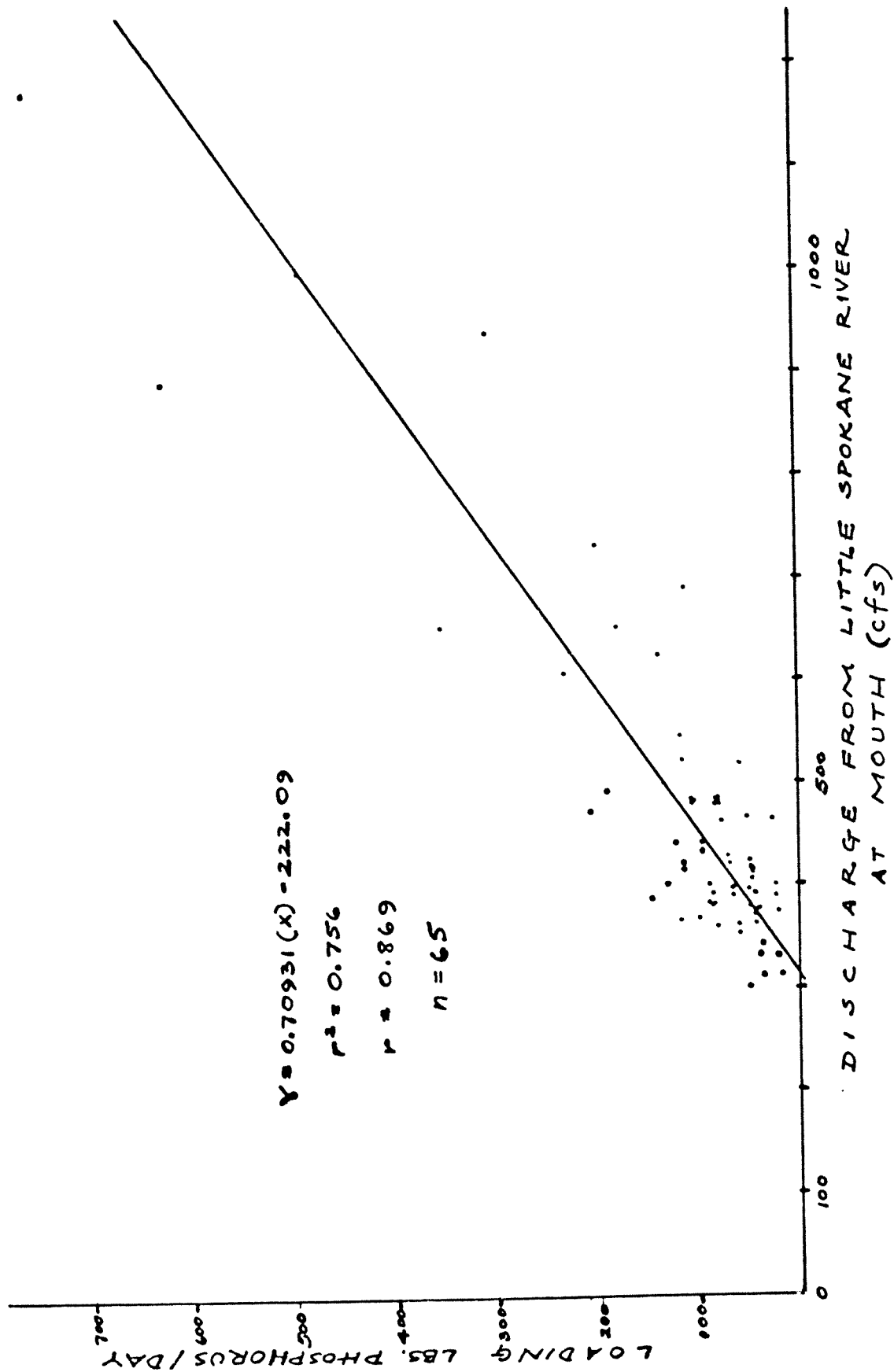
APPENDIX III



Best fit regression line for discharge vs. phosphorus load in the Spokane River at Post Falls showing values of 5000 cfs or less on a line generated from all flows.



Best fit regression line for discharge vs. phosphorus load in Hangman Creek using flows of 100 cfs or less.



Best fit regression line for discharge vs. phosphorus load in the Little Spokane River near its mouth.

